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A COST/BENEFIT ANALYSIS OF A SPRING FROST SURVEY - By R P Rumney

Summary

A frost survey was carried out during the spring of 1985 at a farm near Esher, Surrey, in order to assess the risk to a proposed soft fruit enterprise. Minimum temperatures recorded at two locations on the farm were compared with those recorded on a standard meteorological site at Wisley, about 8 km distant, for which long term climatological records are available. These were used to assess the frost risk at the farm and the losses likely from a proposed crop of plums.

As a consequence of the survey, the farmer changed his cropping plan and substituted 1 ha of raspberries (which are fairly frost tolerant) in the place of plums (which are vulnerable to frost damage at flowering time). Likely crop losses from frost damage were estimated for both the original and revised cropping plans, and the resulting net financial benefit was compared to the cost of conducting the frost survey. Assuming a 20 year productive life for plum trees, the potential benefits over this period were found to outweigh the cost of conducting the survey by more than 10 fold, and amounted to over £40,000 in total.

Introduction

Cost/benefit studies of agrometeorological advice are difficult to make because the information forms only part of the overall advice offered, by an ADAS adviser, to a farmer or grower.

The case described here, however, is relatively straightforward and the opportunity has been taken to perform a simple cost/benefit analysis.

The Survey

i. Method

A frost survey was carried out near Esher, Surrey to assess the frost risk to a proposed fruit enterprise.

The site lies adjacent to the River Mole with a slight slope towards the west. The River Mole valley at this point forms a shallow depression with slightly higher ground to the east and west, thus forming a shallow potential frost hollow.

The area under consideration amounted to around 3.5 ha, upon which the grower intended to grow 2 ha of plums, 1 ha of apples and 0.5 ha of cherries. All three crops are prone to frost damage at flowering time, but plums and cherries flower about 3 weeks earlier (mid April) than apples and are therefore much greater risk from frost damage.

Minimum temperatures were measured at two locations on the farm and at two heights at each location for the period mid March to mid May 1985. At the eastern site, furthest from the river, minimum temperatures were measured at

1.2 m in both a sandwich screen and cocoa tin for comparative purposes. At the western site, approximately 50 m from the river and 100 m from the eastern site, the minimum temperature was measured in a cocoa tin at 1.2 m. Minimum temperatures were also measured at both sites at 0.5 m using cocoa tins. Temperatures read in the sandwich screen were compared directly with those measured at Wisley in a Stevensons screen on a standard meteorological site. Wisley lies about 8 km to the south west of the farm and has long term (1904 to date) temperature records.

Wass (1983) found a mean difference of less than 0.1°C between minimum temperatures measured in a sandwich screen and a Stevenson screen.

ii. Results

Table 1 shows mean minimum temperatures at each site for all occasions and for radiation occasions only, together with the mean difference between Wisley and each site both before and after correcting for the effect of cocoa tin exposure. It can be seen that minimum temperatures at the farm are generally lower than at Wisley. At 1.2 m minima at the western site at the farm are about ½°C lower than at the eastern site. Minima at 0.5 m are approximately 1°C lower than at 1.2 m, and nearly 2½°C lower than at Wisley.

TABLE 1

MEAN MINIMUM TEMPERATURES AT WISLEY AND AT THE FARM FOR MARCH 19 TO MAY 15 1986 FOR ALL OCCASIONS AND RADIATION OCCASIONS ONLY

SITE	MEAN MIN. (°C)		WISLEY - SITE (°C)		WISLEY - SITE - CORRECTION (°C)	
	ALL	RADN. ONLY	ALL	RADN. ONLY	ALL	RADN. ONLY
WISLEY	4.4	1.4				
EAST 1.2m	4.1	0.5	0.3	0.9	0.2	0.8
EAST 0.5m	2.9	- 1.1	1.5	2.5	1.4	2.4
WEST 1.2m	3.6	- 0.1	0.8	1.5	0.7	1.4
WEST 0.5m	2.7	- 1.0	1.7	2.4	1.6	2.3

Note "Screen - Cocoa Tin" correction = 0.1°C for all occasions.

Frost damage to top fruit is likely when air temperatures fall below -1.0°C, with the degree of damage increasing with decreasing temperatures below this level. A minimum temperature lower than -2.2°C on two or more nights is likely to result in a near 100% crop loss in plums. Two nights with temperatures between -1.0° and -2.2°C are likely to cause losses of between 50% and 75%. A single night with a minimum temperature between these values is likely to cause proportionally smaller losses.

Table 2 shows expected frequencies of minima below -1.0°C and -2.2°C at Wisley and at the farm after specified dates and before June 2nd. Frequencies for Wisley are derived from Roe (1981).

PROBABILITY OF MINIMUM TEMPERATURES BELOW -1.0°C AND -2.2°C AT WISLEY AND THE FARM (1.2 m and 0.5 m) (NO OF YEARS IN 10)

Date	Wisley (1.2 m)		Farm (1.2 m)		Farm (0.5 m)	
	<-1.0°C	<2.2°C	<-1.0°C	<-2.2°C	<-1.0°C	<-2.2°C
1 Apr-2 Jun	8.0	4.3	>9.5	7.7	>9.5	>9.5
8 Apr-2 Jun	7.3	3.3	9.1	6.9	>9.5	9.2
15 Apr-2 Jun	6.4	2.1	8.3	5.9	9.2	8.4
22 Apr-2 Jun	5.3	1.0	7.6	4.7	8.7	7.6
29 Apr-2 Jun	4.1	<0.5	6.7	3.7	8.0	6.8
6 May-2 Jun	1.4	<0.5	3.2	1.0	5.1	3.3
13 May-2 Jun	0.8	<0.5	2.1	0.6	3.7	2.2
20 May-2 Jun	0.5	<0.5	1.2	<0.5	2.0	1.3
27 May-2 Jun	<0.5	<0.5	0.9	<0.5	1.2	0.8

Cost/Benefit Analysis

i. Assessing the Risk to the Crop

The risk of frost damage to a fruit crop depends on the occurrence of frost during flowering, which is the most vulnerable stage of development. For plums this normally commences in mid-April, and for apples in early May and lasts for about 10 days. Estimates of frost risk at these times of year made from table 2 will probably be overestimated since the table gives the risk of frost occurrence from specified dates until June 2nd. At Wisley, for the period 1959-84, approximately one third of all frosts recorded between April 15th and June 2nd occurred after the end of April, and therefore after the time of highest risk to plums. Assuming an initial flowering date for plums of about April 15th, the frost risk at the farm at 1.2 m is approximately 8½ (8.3) years in 10 for a minimum of <-1.0°C and 6 (5.9) years in 10 for a minimum of <-2.2°C (table 2). The risk of two or more nights with minima below -2.2°C (causing near to 100% crop loss) is therefore approximately 3½ years in 10 (0.59 x 0.59). Similarly, the risk of two or more nights with minima below -1.0°C (causing about 50% crop loss) is approximately 7 years in 10 (0.83 x 0.83). This assumes frosty nights to be independent of each other. In practice this is not so but the difference is small; eg, at Wisley the probability of two or more nights with minima below -1.0°C calculated on the basis is approximately 4 years in 10 (0.64 x 0.64) whereas examination of daily records yields an estimate of 3.8 years in 10 - a small difference. However, since these assessments of risk cover the period up to June 2nd, the risk at flowering time is rather less than this. The risk of total crop failure at the farm was therefore estimated as 1 year in 4, and the risk of a partial failure (assumed to be 50% crop loss) was taken to be 1 year in 2.

ii. Revised Cropping Plan

In the light of the frost prone nature of the site, the grower modified his cropping plan to reduce potential losses. Whilst retaining the proposed areas of cherries and apples, the area of plums was halved to 1 hectare, and the area of raspberries (already being grown) increased to take their place - since raspberries are fairly frost tolerant. As the enterprise is run largely on a PYO/Farmshop basis, the scope for switching entirely into a frost tolerant crop such as raspberries is restricted by market demand and the need to offer a range of fruit to the customer.

iii. Estimated Gross Margins

Establishment costs, variable costs and output for plums were taken from figures given in MAFF publication "Gross Margin Budgets for Fruit Crops, Nursery Stock and Bulbs 1985", which gives a yield for plums of 15 tonnes/ha and a price of £370/tonne. For raspberries, the figures are based on those given in the figures ADAS SE Region publication "Starting a PYO Enterprise", which gives a yield of 7 tonnes/ha and a price of £1100/tonne. For both crops variable costs were based on those for a PYO enterprise. The productive life span of plums was assumed to be 20 years but raspberries were assumed to have to be established twice during that time. Estimated losses of plums due to frost were based on the frost survey, and simply estimated at 37.5% of yield per year (100% loss 1 year in 4, 50% loss 1 year in 4, no loss 2 years in 4). Losses for raspberries were assumed to be negligible. Table 3 shows output variable costs and gross margins for 1 ha of plums (with and without frost loss) and 1 ha of raspberries.

TABLE 3 OUTPUT, FROST LOSS, VARIABLE COST AND GROSS MARGIN FOR 1HA OF PLUMS AND 1HA OF RASPBERRIES OVER A 20 YEAR PERIOD

YEAR	PLUMS						RASPBERRIES		
	NO FROST LOSS			37½% FROST LOSS			NO FROST LOSS		
	Output (£)	Var Costs (£)	Gross Margin (£)	Output (£)	Var Costs (£)	Gross Margin (£)	Output (£)	Var Costs (£)	Gross Margin (£)
1	0	2450	-2450	0	2450	-2450	0	660	-660
2	0	175	- 175	0	175	- 175	165	390	-225
3	185	200	- 15	115	200	- 85	1650	565	1085
4	1480	225	1255	925	225	700	4400	565	3835
5	2590	250	2340	1620	250	1370	7700	565	7135
6	4440	250	4190	2775	250	2525	7700	565	7135
7 - 10 (per Year)	5550	250	5300	3470	250	3220	7700	565	7135
11	5550	250	5300	3470	250	3220	0	660	-660
12	5550	250	5300	3470	250	3220	165	390	-225
13	5550	250	5300	3470	250	3220	1650	565	1085
14	5550	250	5300	3470	250	3220	4400	565	3835
15 - 20 (per Year)	5550	250	5300	3470	250	3220	7700	565	7135
TOTAL (20 Years)	86395	6550	79345	54015	6550	46965	104830	11140	93690
AVERAGE (per Year)	4320	327	3965	2700	327	2350	5240	557	4685

iv. Benefits

The figures in Table 3 take no account of inflation, but may nevertheless be used to compare the margins which can be expected from the two crops, and thus to assess the potential benefits which may be derived by switching out of plums into a more frost tolerant crop such as raspberries. Had the survey shown the frost risk to be negligible or small, then the grower would have grown either plums or raspberries with minimal crop losses. The differenc in gross margins in this situation is relatively small (£4685/ha for raspberries compared to £3965/ha for plums). However, on the assumption of an average crop loss of 37½% for plums, based on the results of the survey, this difference becomes far more significant, with a reduction in gross margins from £3695/ha to £2350/ha. Thus, by replacing 1ha plums by raspberries the grower has doubled potential gross margin from £2350 to £4685. Over a typical 20 year period this benefit amounts to £46,700.

v. Costs

It is more difficult to assess the costs of conducting the survey than the benefits since at present no charge is made to the grower for this type of service. However we may divide the costs into fixed and variable elements. The cost of purchasing the equipment used to conduct the survey (thermometers, screens, etc) may be considered as a fixed cost since this equipment was already available and was not purchased specifically for this study. The costs associated with the climatological data for Wisley may also be considered in this category. The costs specifically associated with the survey are the variable costs - mainly the manpower costs involved in gathering and analysing the data, advising the grower of the results and the grower's time spent in reorganising his cropping plan.

The ADAS/Met Office manpower input is estimated at approximately 10 man days of Grade III/HSO time spent in (a) assessing the site and setting up the survey, (b) analysing the data and writing up the results, and (c) advising the grower of the findings of the survey and on consequential courses of action. The grower's time associated with the survey itself (ie reading the thermometers and recording the results) is relatively small, amounting to probably no more than 10 man hours. However, a further 3 man days, say of the grower's time should be taken into account to allow for the time taken to decide on a change in cropping plan as a result of the survey.

The variable costs are therefore estimated as:-

10 hours for grower @ £25/hour	£250
10 days for agrometeorologist/horticultural Adviser @ £36/hour*	£2665
3 days for grower @ £25/hour	£600
Travel costs for agrometeorologist/horticultural Adviser	£100
TOTAL	£3615

*Standard Met Office rate for HSO.

The cost of the survey (£3615) must be considered as part of the initial outlay for the revised cropping plan, together with the establishment costs.

Table 4 summarises the costs and benefits of the original and revised cropping plans during the first 6 years. For the original cropping plan (2 ha of plums the initial outlay is not recovered until the 6th year (3rd or 4th cropping year), assuming an average frost loss of 37½%. For the revised cropping plan (1 ha plums and 1 ha raspberries) the initial outlay, including the frost survey costs, is recovered in the 5th year due to the earlier production and larger gross margins attainable with raspberries.

TABLE 4 COSTS AND BENEFITS FOR ORIGINAL AND REVISED CROPPING PLANS (UP TO YEAR 6) (37½% FROST LOSS)

Year		ORIGINAL PLAN (2 ha PLUMS)		REVISED PLAN 1ha PLUMS 1 ha Raspberries	
		Costs	Benefits	Costs	Benefits
1	Establishment	4900	-	3110	-
	Frost Survey	-	-	3615	-
2	Gross Margin	350	-	400	-
3	"	170	-	-	1000
4	"	-	1400	-	4535
5	"	-	2740	-	8505
6	"	-	5050	-	9660

CONCLUSIONS

This paper outlines the costs and resulting benefits which may be expected to accrue from a typical frost survey. Over a twenty year period the benefit in this case study outweighs the cost of the survey by more than ten fold (£46,700 vs £3,610). The size of the investment involved in even a modest fruit enterprise such as this make an accurate assessment of the potential frost risk at the site absolutely essential. For larger enterprises obviously the resulting benefits are likely to be proportionately greater when compared to the cost of the survey and would therefore strengthen the justification for carrying out such a survey.

Glossary of Terms

ESTABLISHMENT COSTS are those costs directly associated with establishing the crop eg cost of cultivation, costs of plants and planting, cost of initial fertiliser applications etc.

FIXED COSTS are those costs which either cannot be readily allocated to a specific enterprise or will not vary with small changes in the scale of the individual enterprises, eg cost of non enterprise specific machinery, rent and rates payable on land etc.

VARIABLE COSTS are those costs which can both be readily allocated to a specific enterprise and will vary in approximately direct proportion to changes in the scale of that enterprise, eg cost of chemical applications and fertilisers, casual labour etc.

THE GROSS MARGIN of an enterprise is the enterprise output less its Variable Costs.

References

Roe C.P. (1981) Probability curves of minimum temperatures below stated thresholds during spring in SE England. Agric Memo 915 Meteorological Office, Bracknell, Berks (Unpublished paper)

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Any comments or suggestions on this paper should be sent to the Author.

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